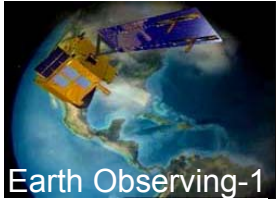


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# Section 20a

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## Carbon-Carbon Radiator (CCR)

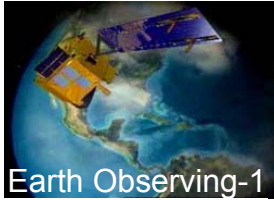


# Carbon-Carbon (C-C)



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- ◆ ***Carbon-Carbon (C-C) - Composite material that uses carbon for both the fiber and the matrix material***
  - *produced in a high temperature furnace in a lengthy process*
- ◆ ***C-C has high thermal conductivity, good strength, and is lighter than Aluminum***
- ◆ ***C-C used in high temperature applications***
  - *Aircraft brakes, Space Shuttle wing leading edge*
- ◆ ***Limited applications elsewhere to date, primarily due to cost and production lead time***

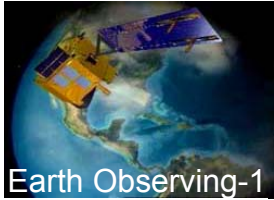


# C-C Spacecraft Radiator Partnership (CSRP)



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- ◆ ***CSRP started by Howard Maahs of NASA Langley and Elizabeth Shinn of Wright Patterson Air Force Base to promote the use of C-C as a radiator material***
- ◆ ***CSRP was an informal partnership with members from government and industry***
  - ***NASA Langley, NASA/Goddard, Air Force at Wright Patterson and Phillips Lab, Naval Surface Warfare Center,***
  - ***TRW, Lockheed Martin, Amoco, B.F. Goodrich, Materials Research, Swales***
- ◆ ***The New Millennium Program's EO-1 mission provided an opportunity for the CSRP to fly a C-C radiator***
  - ***C-C radiator provided by CSRP at “no cost” to NMP***

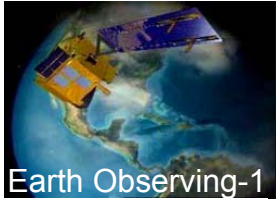


# C-C Radiator on EO-1



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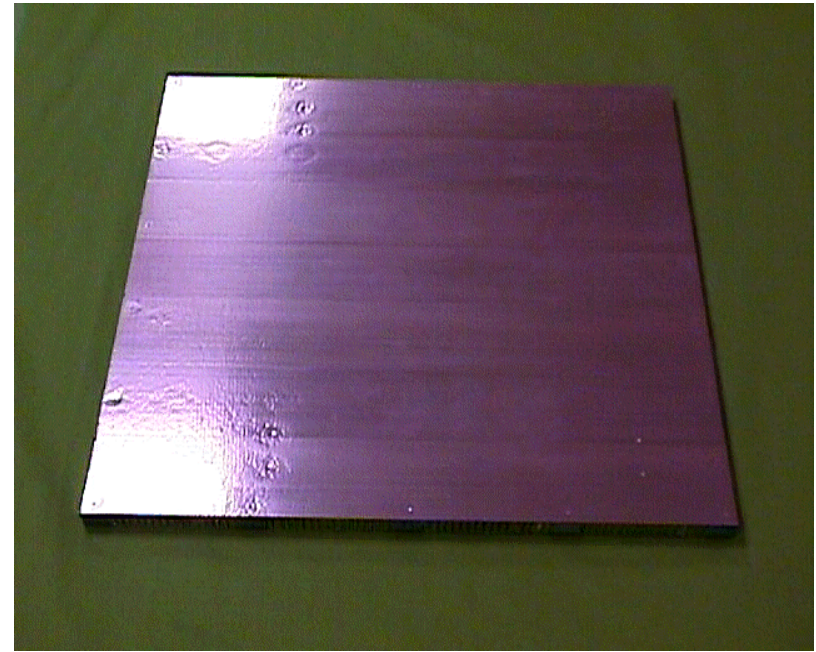
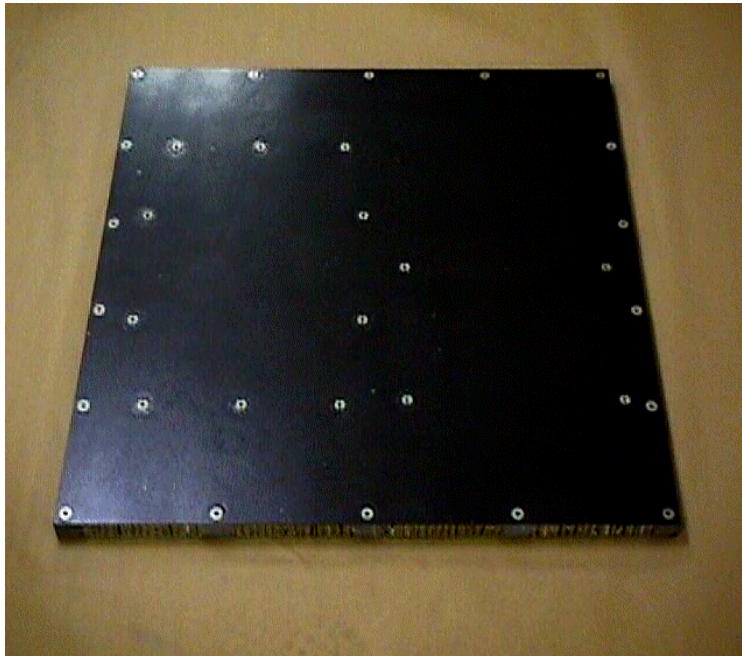
- ◆ *The C-C radiator replaces one of six structural panels on the EO-1 Spacecraft - it is both a radiator and a structural member*
- ◆ *C-C Radiator consists of 1" Al honeycomb with 0.020" C-C face-sheets, approximately 28" by 28"*
  - *Utilizes two plies of P30X carbon fibers with carbon matrix established by Chemical Vapor Infiltration*
  - *Epoxy coated for strength and contamination protection*
  - *Aluminum inserts bonded to honeycomb core for mounting of electronics boxes and attachment to the S/C*
  - *Exterior coated with Silver Teflon for heat rejection*
- ◆ *CSRP delivered one flight unit and one spare to GSFC*
  - *Flight qualification testing completed at GSFC*

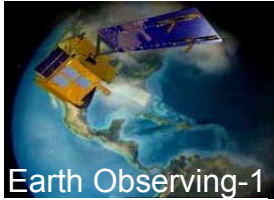


# *EO-1 C-C Radiator*



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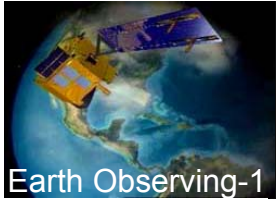


# CCR Technology Validation (Thermal)



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- ◆ ***Verify thermal performance of C-C material meets S/C requirements, evaluate any degradation of thermal conductivity (none expected)***
  - *Thermal conductivity measured by testing (coupon level and panel level Thermal Vacuum (T/V) tests)*
  - *Thermal cycling verified panel integrity*
  - *Thermal model correlated to test results and flight data*
  - *S/C level T/V test provided additional verification, comparison for C-C flight thermistor readings*
  - *Monitor C-C thermistor data on-orbit, along with S/C attitude data*
  - *Correlated flight data with C-C thermal model to verify proper C-C radiator performance*



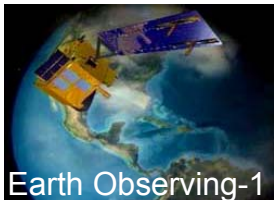
# CCR Technology Validation (Structural / Other)



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- ◆ ***Coupon Level Tests - verify material integrity and strength***
- ◆ ***Panel Level Tests/Analysis***
  - ***Vibration and Strength***
    - *Structural Analysis and Modeling*
  - ***Mass Properties***
  - ***Non-destructive examination (radiography) conducted before and after qualification testing***
- ◆ ***Spacecraft Level Testing***
  - ***Vibration***
  - ***Thermal Vacuum***
  - ***EMI***

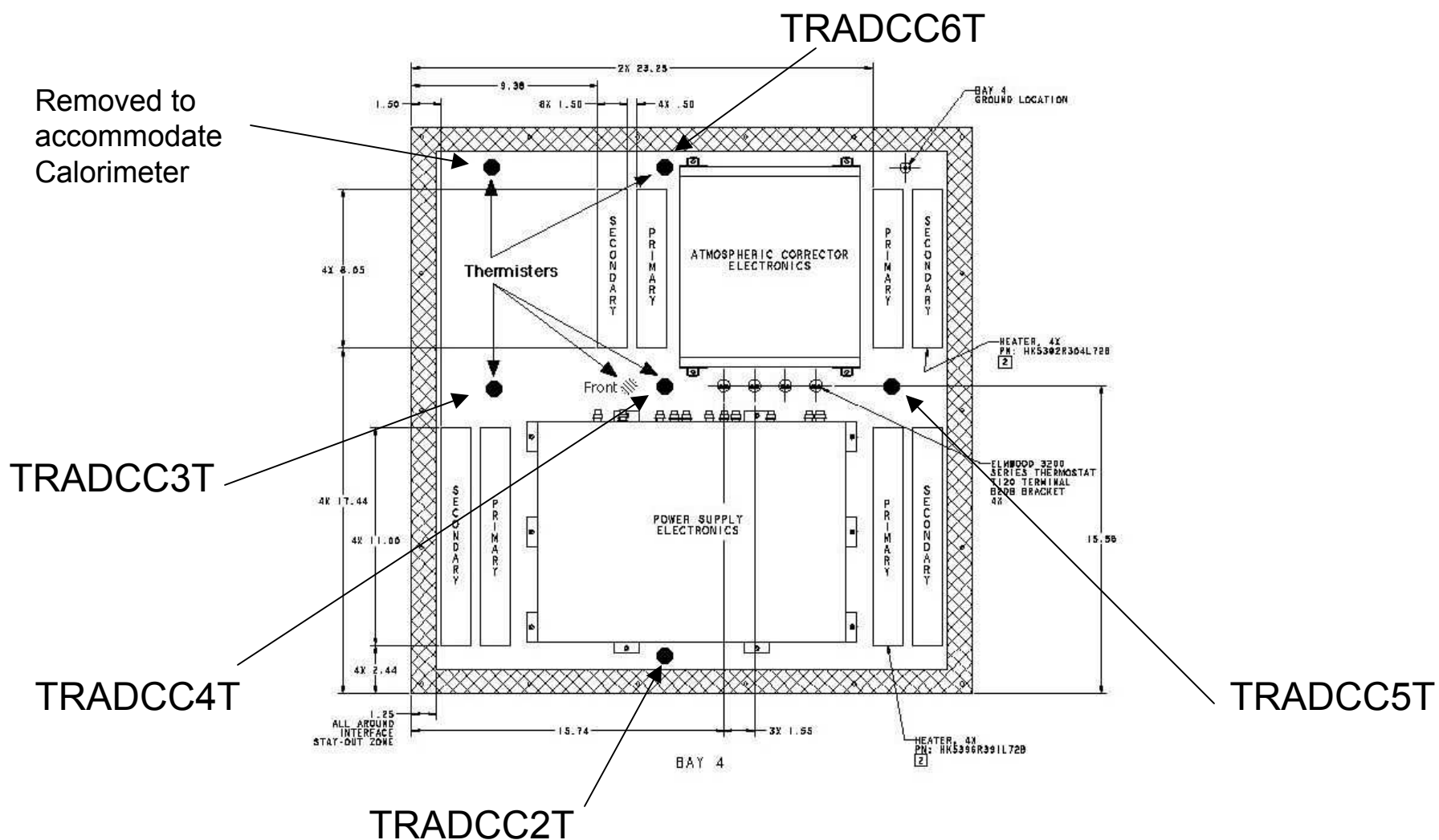




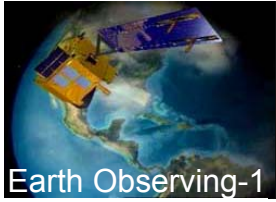
# C-C Radiator Thermistor Layout



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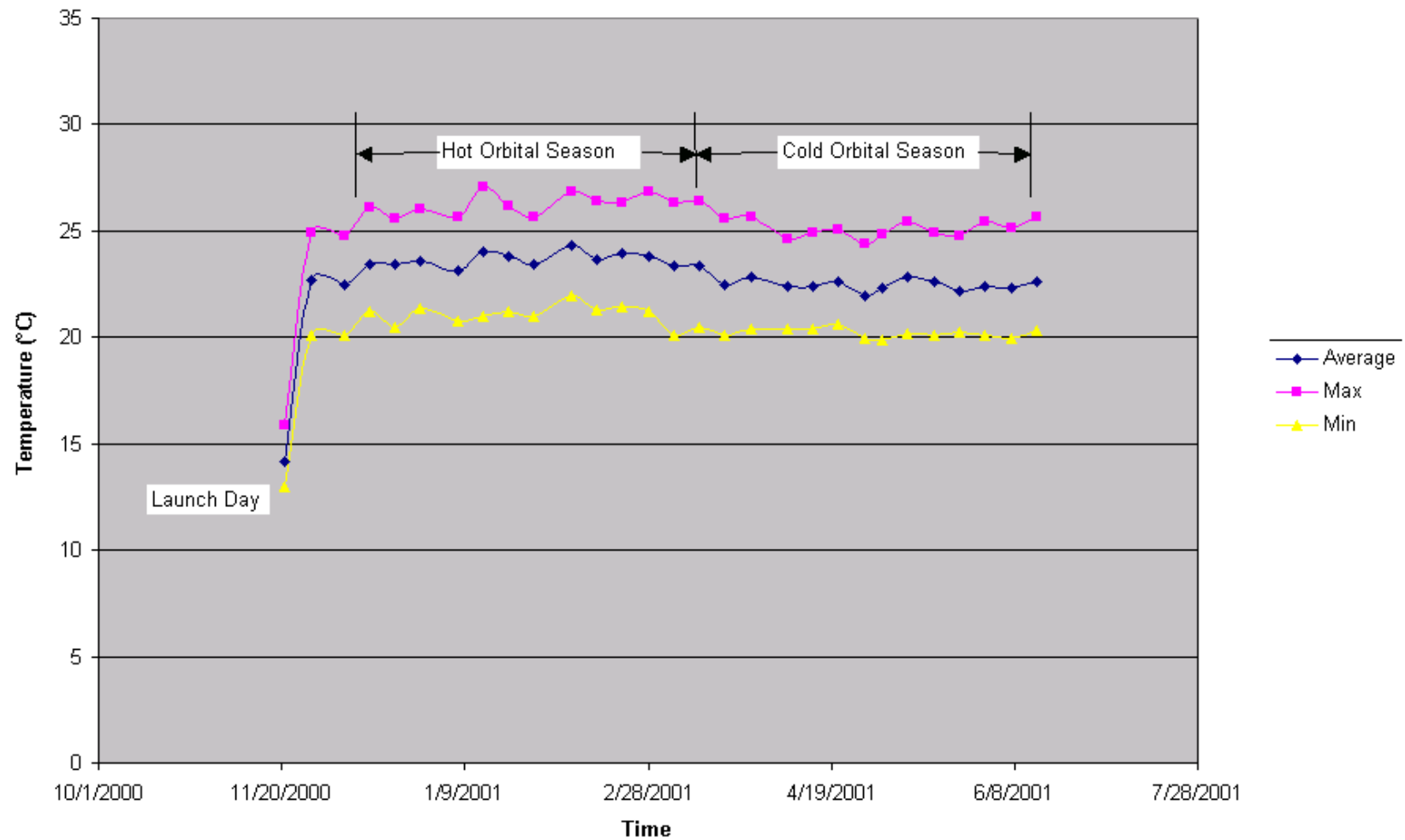


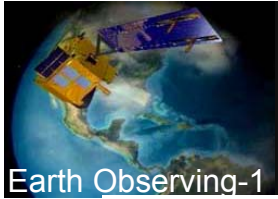
Earth Observing-1

# C-C Radiator (Bay 4T)



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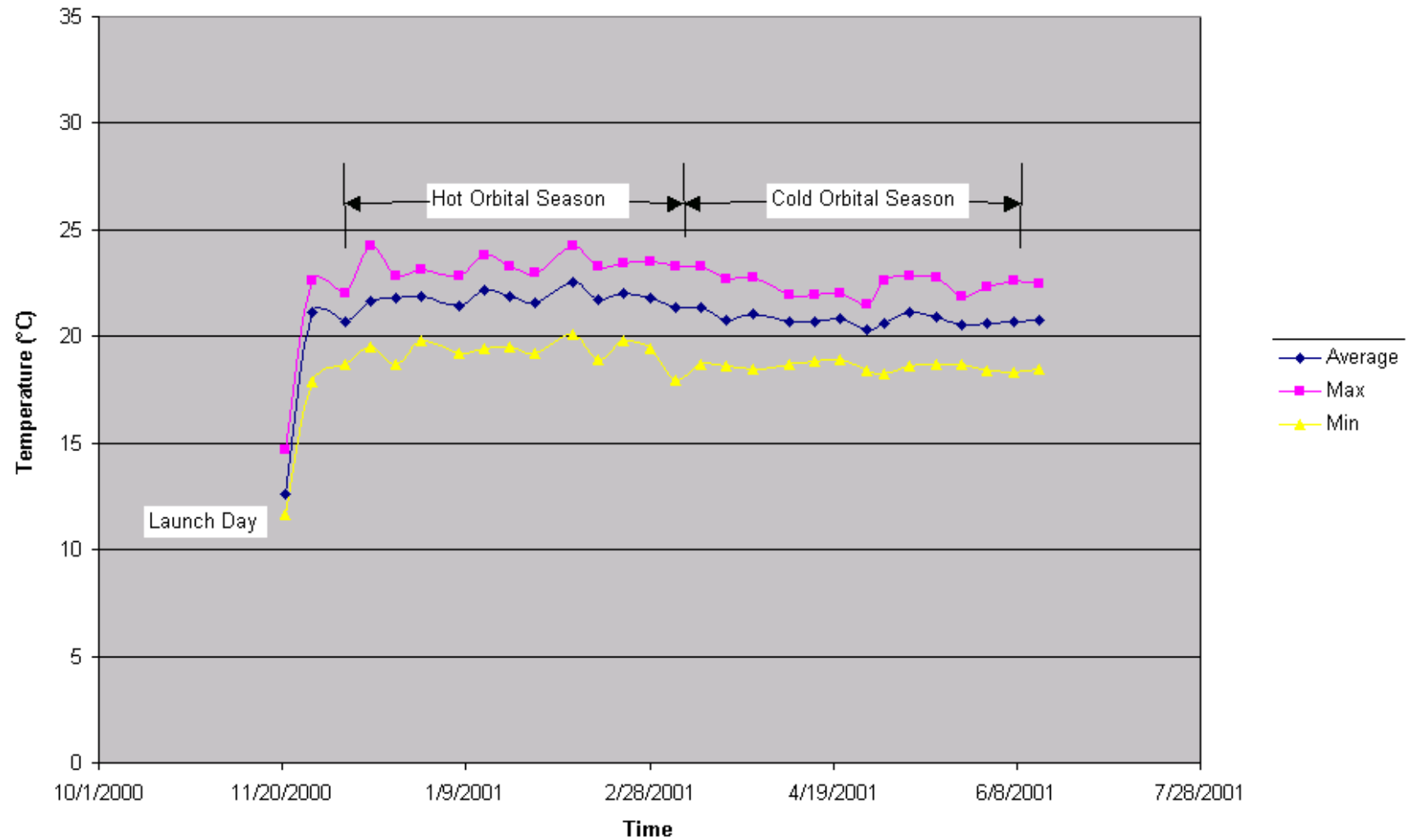


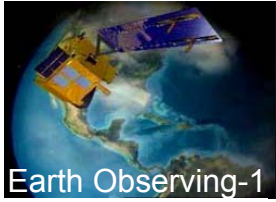
# C-C Radiator (TRADCC2T)



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CC Radiator - TRADCC2T

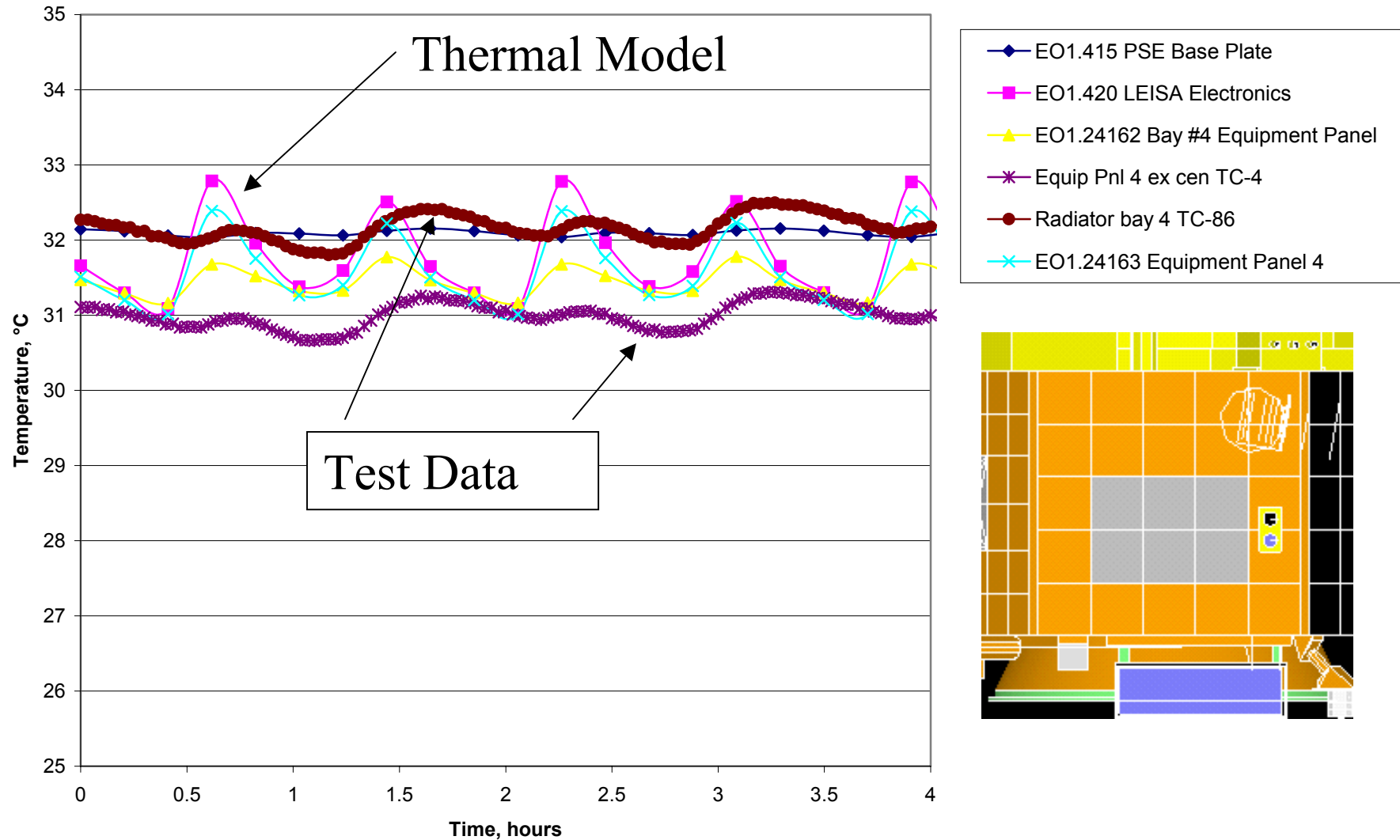


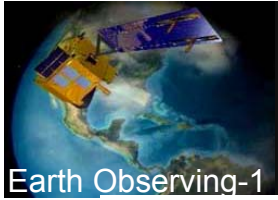


# EO-1 Hot Balance Thermal Model vs. Test Results



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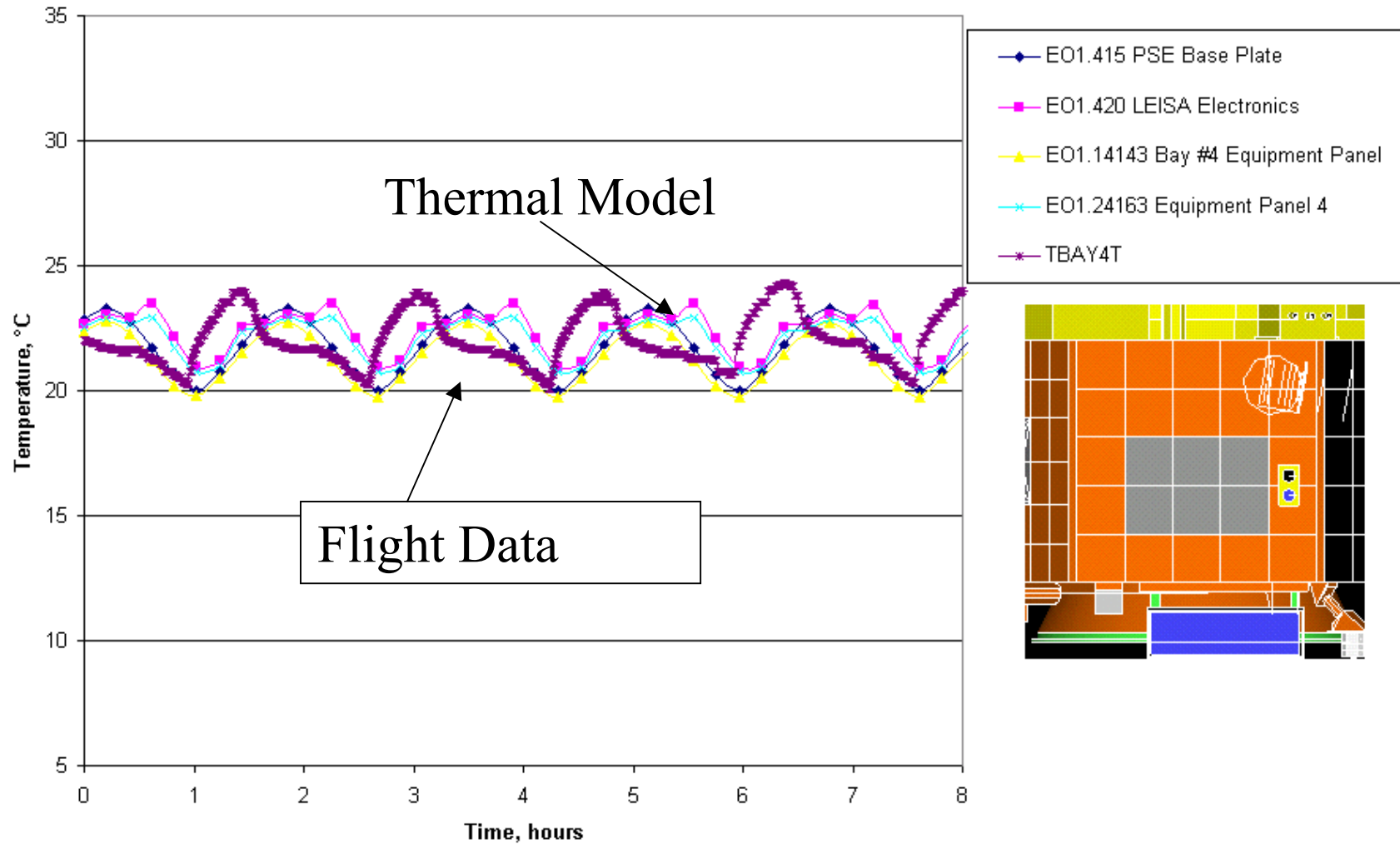


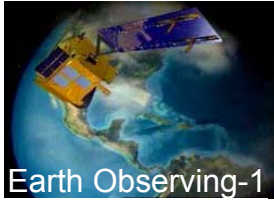
# EO-1 DCE Thermal Analysis Results



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EO-1 DCE (Nominal) Thermal Analysis Results (December 2, 2000)



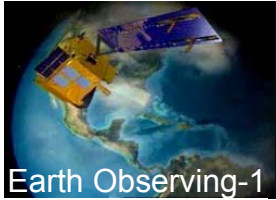


# CCR Technology Transfer / Lessons Learned



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- ◆ ***C-C Radiator technology was successfully validated***
  - *C-C radiator panels can be used to reduce S/C weight*
  - *They can also be used as part of the S/C structure*
- ◆ ***C-C has a niche, especially for high temperatures***
  - *Application on the Solar probe*
- ◆ ***C-C still needs further development (my opinion)***
  - *Reduction in fabrication time and cost - high conductivity “traditional” composites are competitive*
  - *CTE Interface issues with heat pipes*
- ◆ ***Redundancy a good idea - we flew the spare panel***
- ◆ ***Possible follow-on missions: C-C foam for low CTE mirrors/optical benches***



# Summary



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- ◆ ***CSRP was a success - informal inter-agency partnership***
  - ***Thanks to all who contributed - this was a fun job***
- ◆ ***CSRP no longer in business, but manufacturers of Carbon-Carbon are still operating, i.e. B.F. Goodrich, Amoco***
- ◆ ***Thanks to EO-1 project and Swales for this opportunity***